

Using SPC and Trending to Reduce FOD

Presented by:

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ATK Thiokol



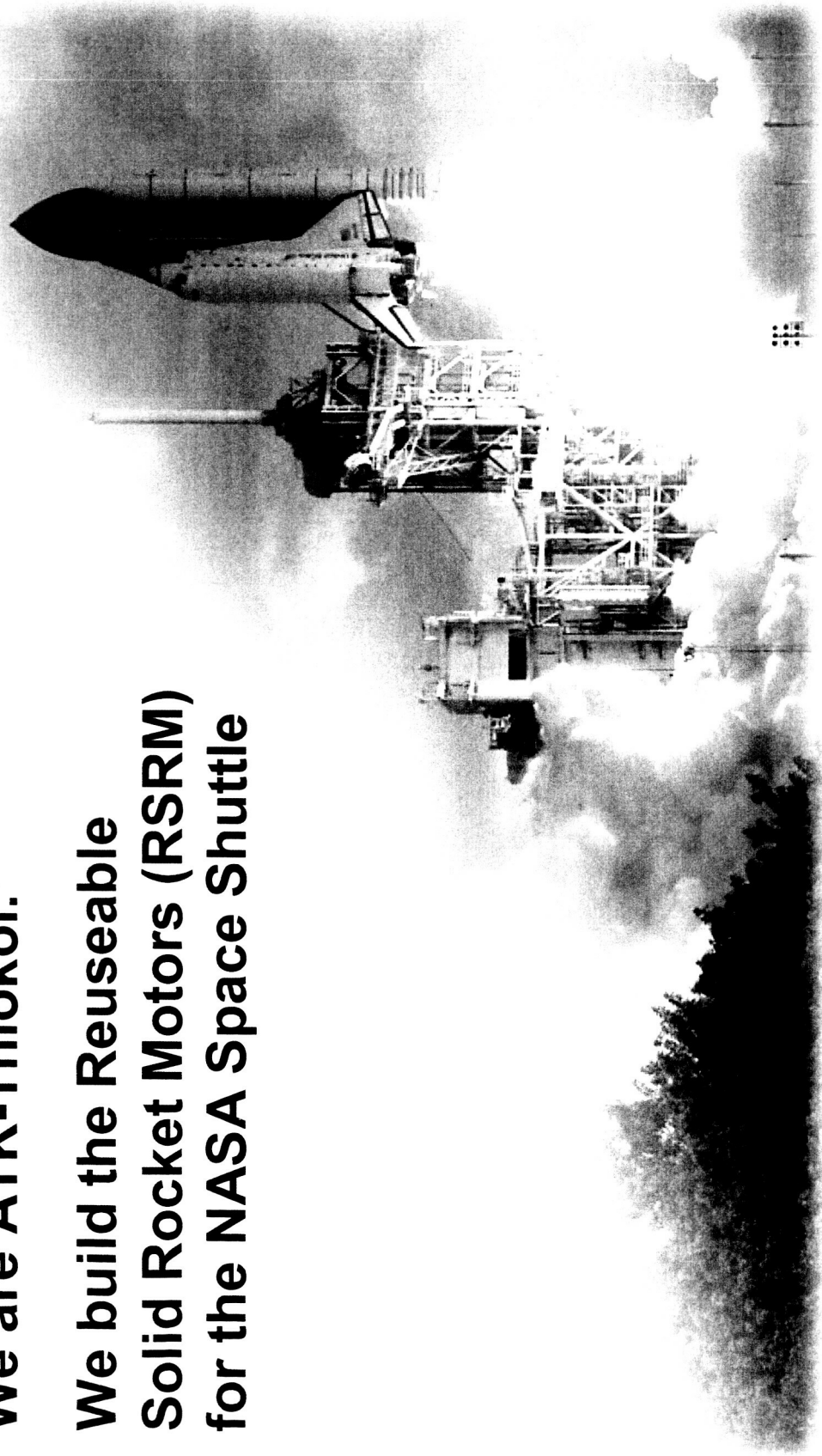
An advanced space and weapon systems company



ATK THIOKOL

Introduction

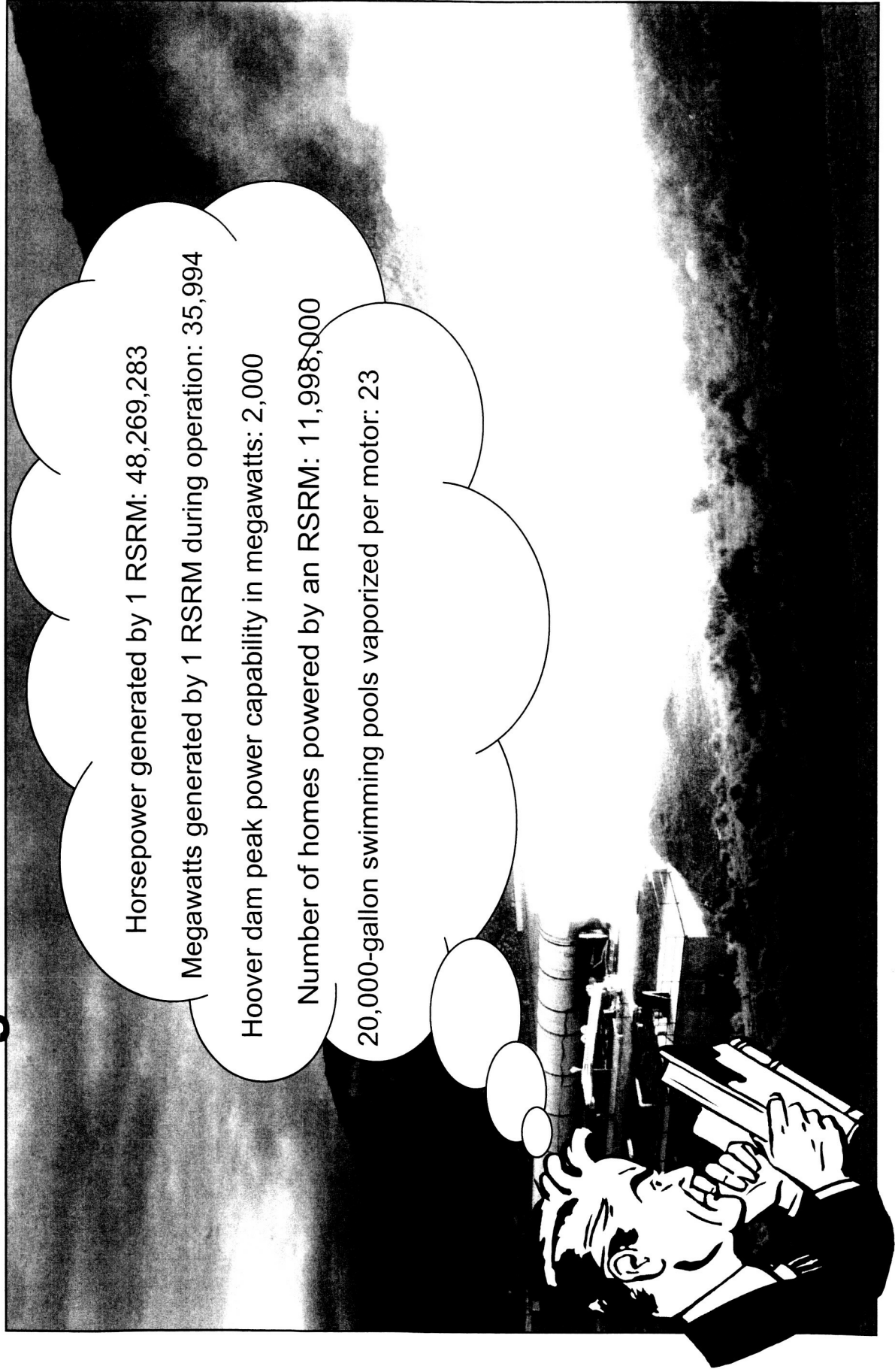
We are ATK-Thiokol.
We build the Reuseable
Solid Rocket Motors (RSRM)
for the NASA Space Shuttle





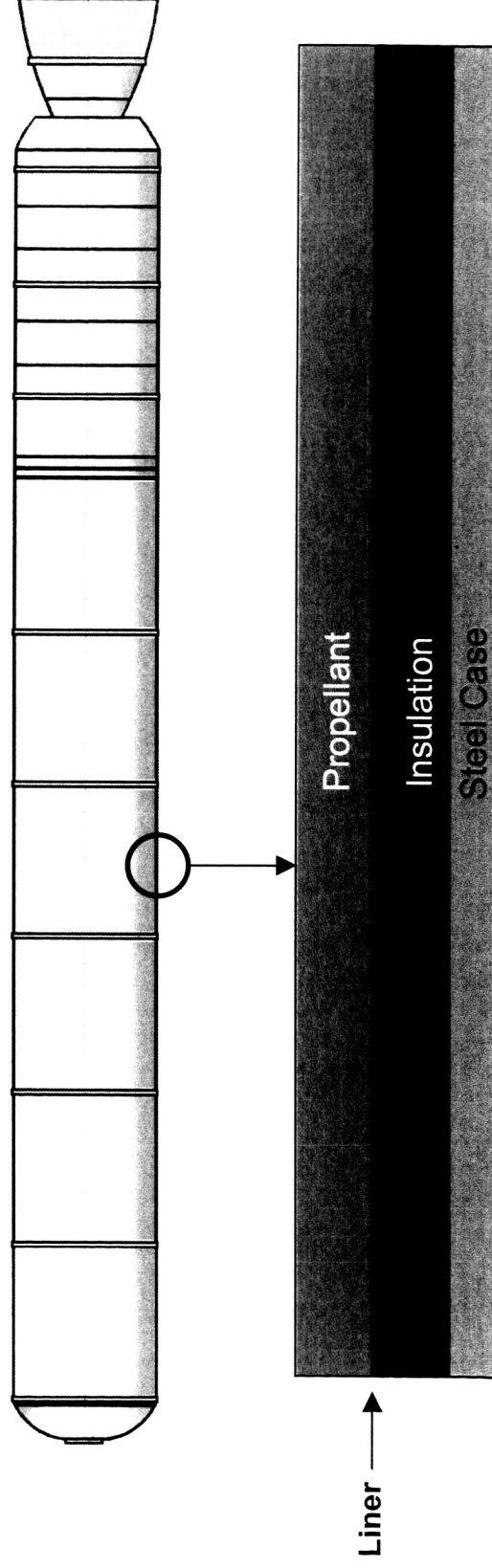
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Amazing Little Known and Less Used Facts



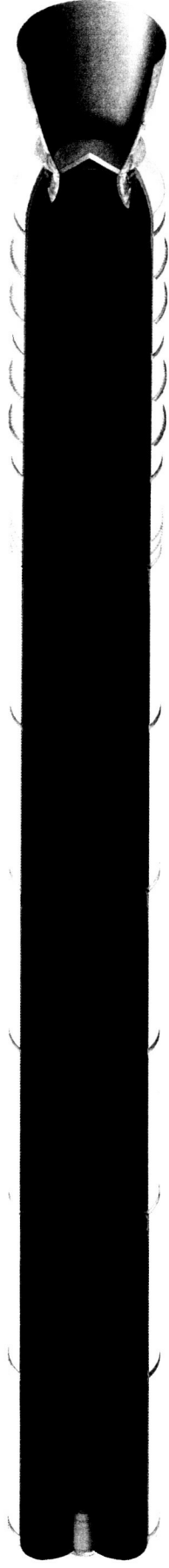
Critical Nature of Rocket Manufacturing

- Many solid rocket components are basically bonded inside the rocket motor
 - Propellant bonds to Liner
 - Liner bonds to Insulation
 - Insulation bonds to Steel Case
- Bondline cleanliness is an important issue



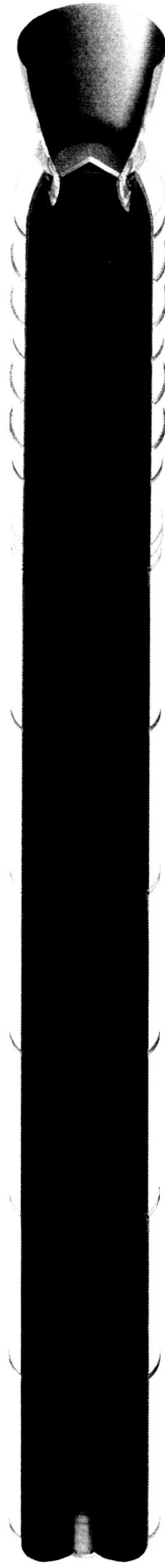
Critical Nature of Rocket Manufacturing

- Solid rocket propellant has it's own set of contamination concerns
- Propellant is a structural mass
- This structure has a critical flaw size
- Foreign debris can create a flaw in the structure
- If the critical flaw size is exceeded, then the capability of the propellant to withstand loads without cracking is compromised, and the propellant grain may crack
 - Loads are created by shrinkage, temperature, motor position, transportation, etc.



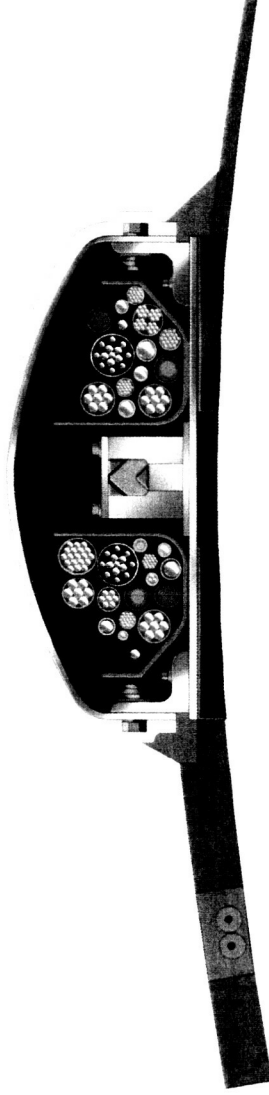
Critical Nature of Rocket Manufacturing

- Foreign objects within solid rocket propellant can act as projectiles when the propellant burns and are expelled out of the motor
- The impact of these objects on other Shuttle components can cause damage



Critical Nature of Rocket Manufacturing

- Components are also bonded to the outside of solid rocket motors.
- If bond loads exceed bond capability, these objects will fall off the rocket motor, and could cause damage during a launch





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ATK-Thiokol Foreign Object Debris (FOD) Philosophy

So, like other Aerospace
organizations, ATK-Thiokol
takes FOD very, very
seriously!

ATK-Thiokol Foreign Object Debris (FOD) Philosophy

- Systems and procedures have been established to prevent foreign objects (FO)
 - Manufacturing areas have identified FO zones
 - Bondlines are prepared in proper environmental conditions
 - Air is filtered and particulate parameters are statistically monitored
 - A contamination free culture has been developed

ATK-Thiokol Foreign Object Debris (FOD) Philosophy

- Management supports FOD prevention, reduction, and elimination efforts
 - Management participates in audits
 - Management participates in Case Studies to attack particular issues
 - Company funding is provided to resolve issues
- Engineering analysis and testing have been done to understand when FOD impacts hardware performance
 - We understand at what levels contamination can affect a baseline
 - Then we operate well within these limits, yet continue to improve
 - We understand what sizes of contamination can affect the propellant structure
 - Then we screen raw materials with screens that have been properly sized to protect the hardware
 - Require vendors to supply “clean” raw materials
 - ATK-Thiokol produces > 15,000,000 lbs of propellant each year and finds < 50 grams of FOD in the propellant stream – yet we need to continue to improve

FOD Trending and SPC at ATK-Thiokol

Philosophy

- We believe in collecting and using data to improve
 - In God We Trust. All others bring data
 - You can't improve if you don't measure
 - Without an organization which can disseminate and act upon knowledge gained, the knowledge is gained in vain
 - Understand random variation as compared to special cause variation
 - Random – inherently part of the process hour after hour, day after day, and affects everyone working in the process
 - Special – Causes not part of process all of the time
 - Don't try to eliminate everything all at once. It overwhelms the teams. Pick the top culprits
 - Never think you're good enough

USE SPC and TRENDING TO REDUCE FOD

Trending and Statistical Process Control (SPC)

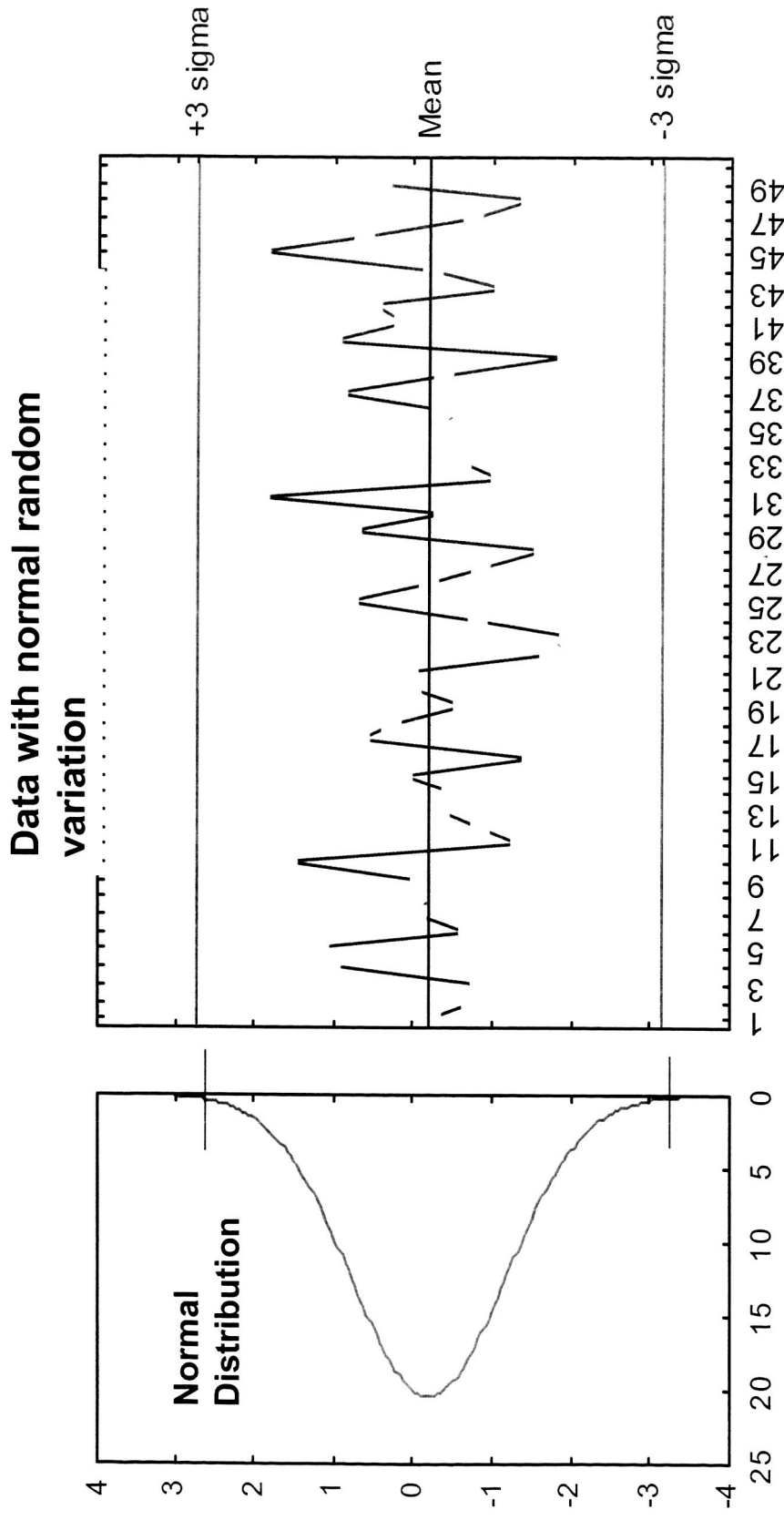
Basic Philosophy

- SPC is the use of statistics to help operators and engineers understand when the process is not performing as intended
 - SPC uses 3-sigma limits and other trends or rules to flag unusual conditions
 - 7 points increasing
 - 8 points on one side of the mean
 - 2 of 3 points outside of 2 sigma limits
- 3-sigma limits basically mark the spot at which only 3 out of 1000 points will occur, based on random variation, unless an assignable cause is present

Trending and Statistical Process Control (SPC)

Basic Philosophy

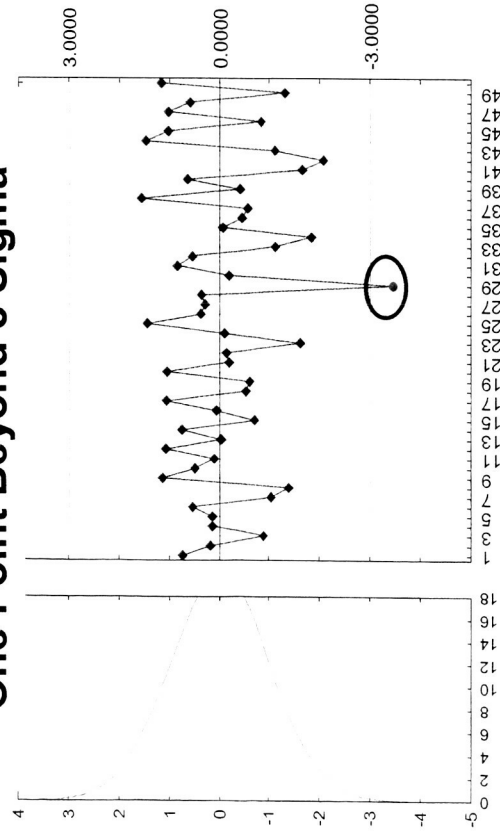
- Generic SPC Chart



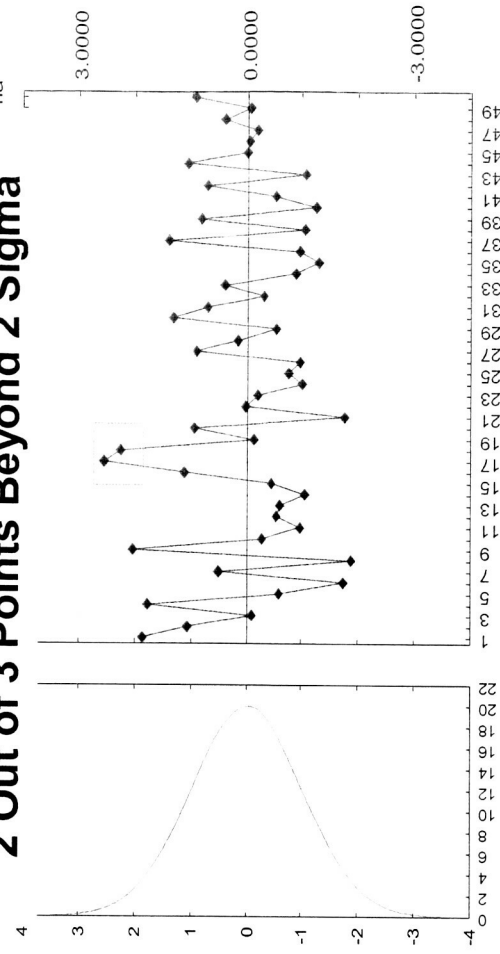
Trending and Statistical Process Control (SPC)

Special Cause Variation

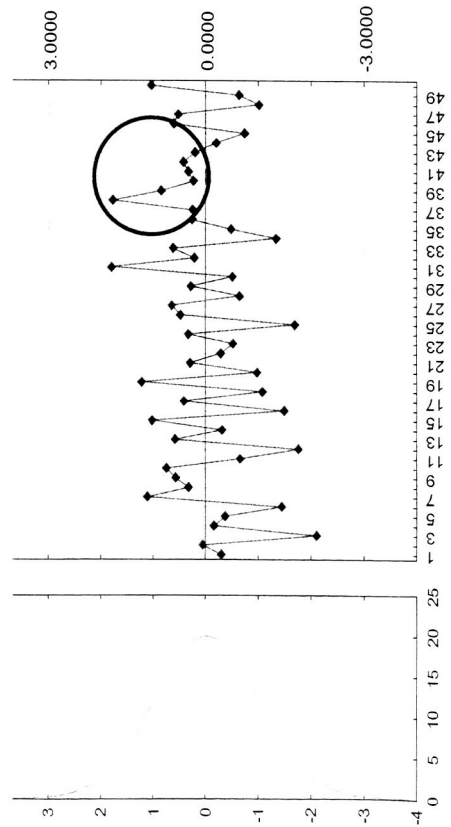
One Point Beyond 3 Sigma



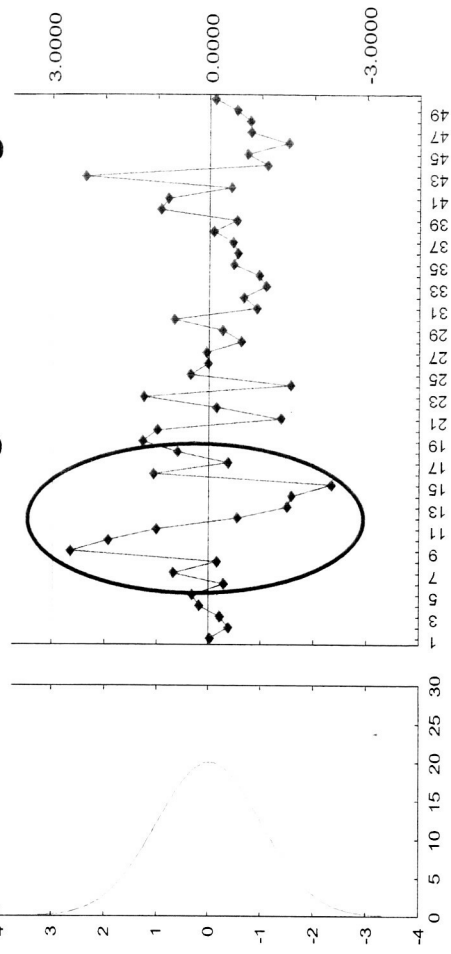
2 Out of 3 Points Beyond 2 Sigma



8 Points in a Row on One Side of Centerline



7 Points Increasing or Decreasing

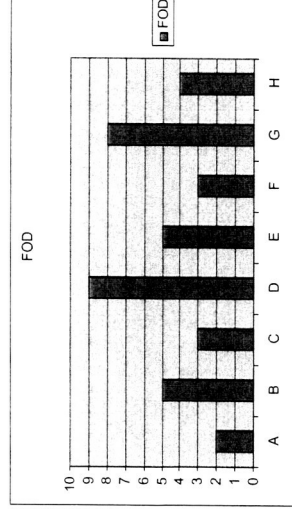


FOD Trending and SPC at ATK-Thiokol

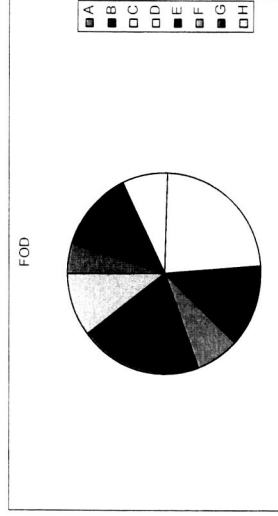
Trending

- Trending is the charting of data in various forms, including:

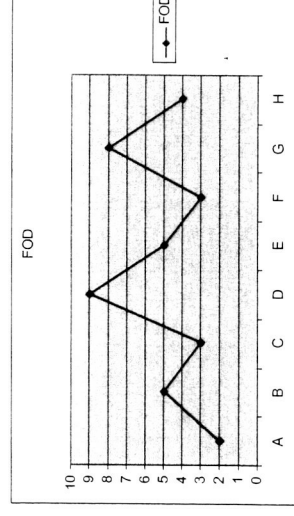
- Bar Charts



- Pie Charts



- Line Charts



FOD Trending and SPC at ATK-Thiokol

Specific Instances

- ATK-Thiokol uses trending and SPC to reduce contamination in the following processes
 - Ambient and compressed air
 - Hydrocarbons
 - Moisture
 - Particulate
 - Propellant processing FO zones
 - Trend by building and type of FO
 - Propellant raw material screens
 - Trend by process and type of FO



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FOD Trending and SPC at ATK-Thiokol

Contamination in Air

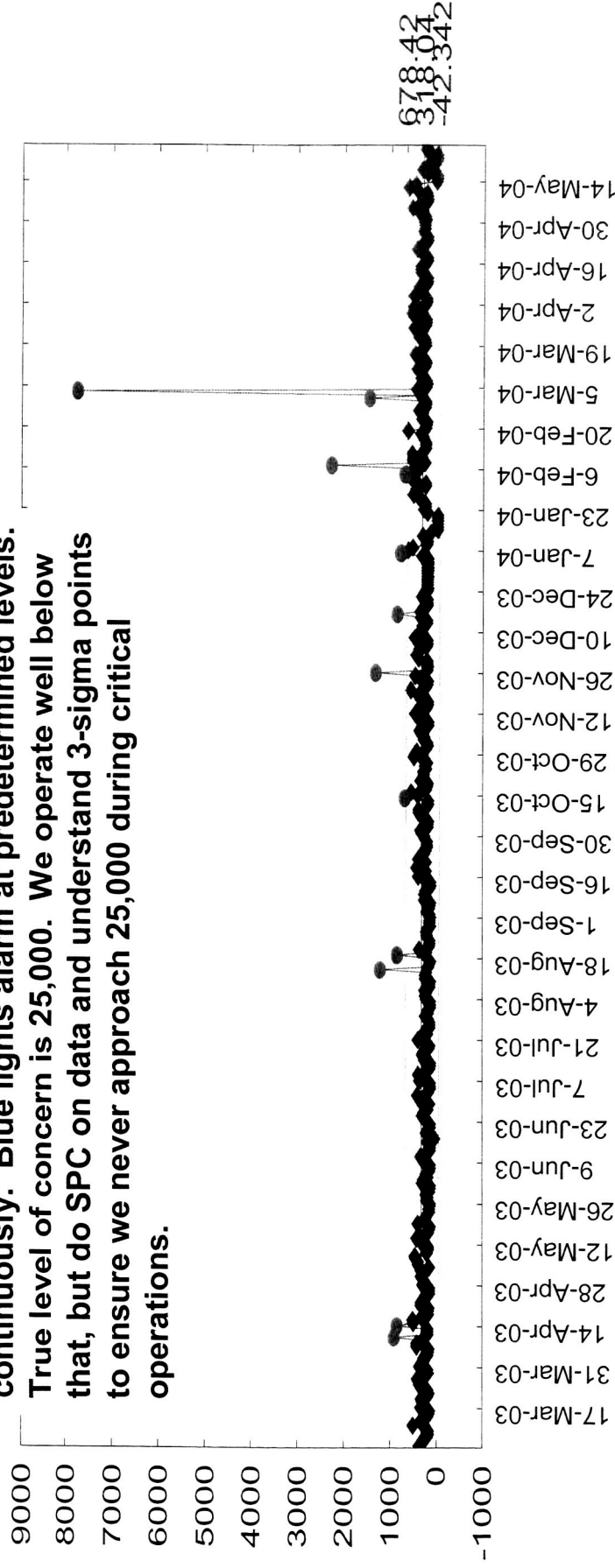
- Particulate Chart

Level of Concern

25,000

Lessons Learned: Air particulate data is monitored continuously. Blue lights alarm at predetermined levels. True level of concern is 25,000. We operate well below that, but do SPC on data and understand 3-sigma points to ensure we never approach 25,000 during critical operations.

Years



Limits Calculated from All Data

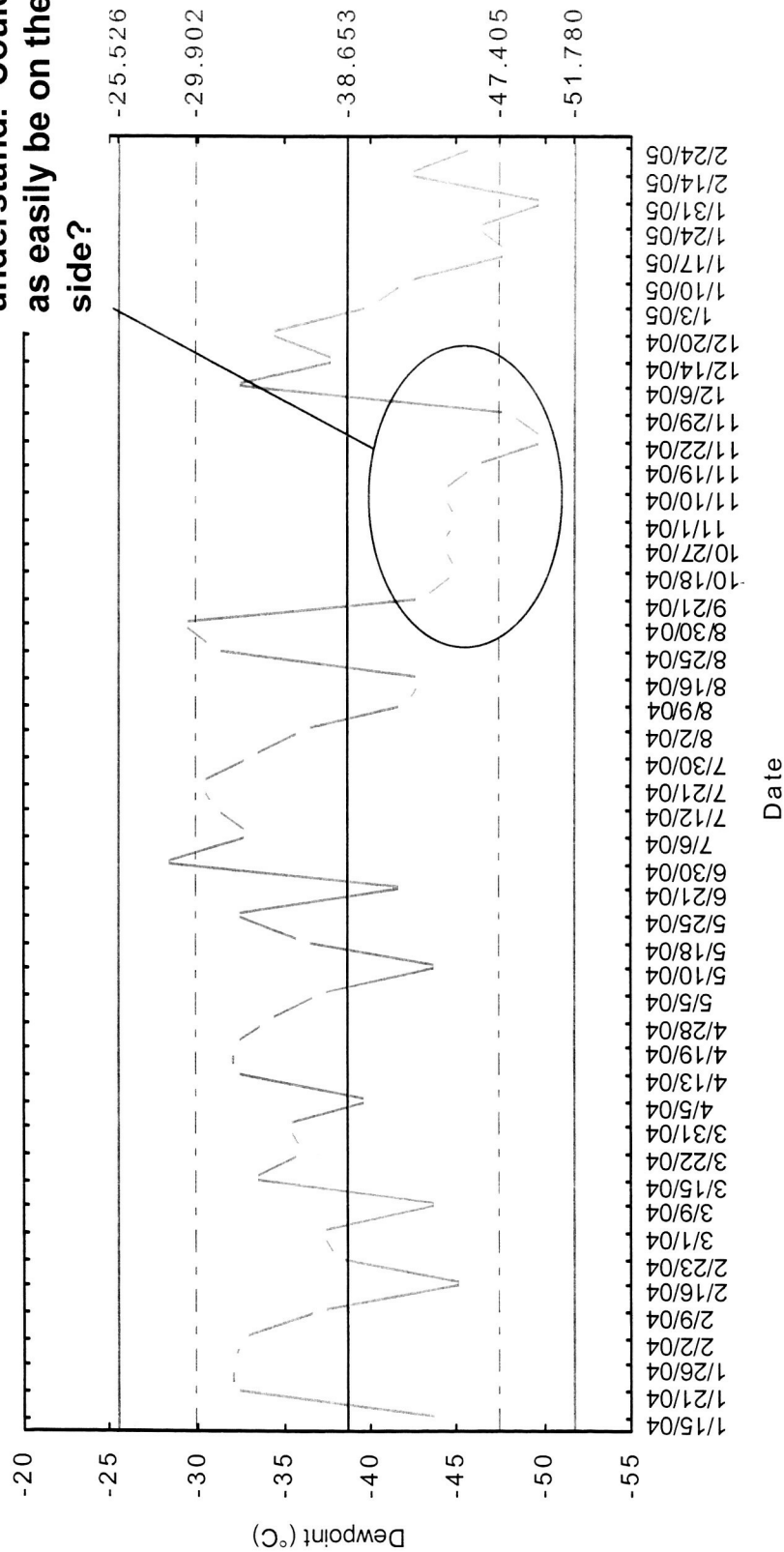
FOD Trending and SPC at ATK-Thiokol

Nitrogen Dewpoint

- Moisture is a contaminant for aluminum powder

X Chart; variable: M-314 Second Floor Nitrogen Dew point
 X: -38.653 (-38.653); Sigma: 4.3757 (4.3757); n: 1.

Lessons Learned: Even though a lower dewpoint is better, 8 points on a side indicates process isn't in control. Need to understand. Could it just as easily be on the high side?



FOD Trending and SPC at ATK-Thiokol

Air Monitoring – Who Does What and Lessons Learned

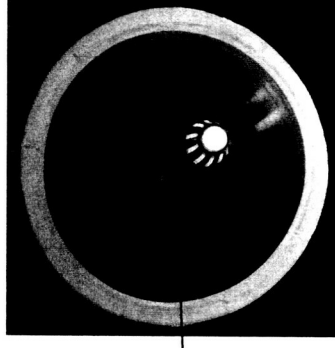
- Automated system collects data, which improved ability to do SPC
- Blue light system warns Operations if particulate count goes out of specification
- Customer (NASA) paid for system as a way to improve quality
- Engineers showed that particulate count does affect bondline strength
 - People Need to believe that the data being collected is worth collecting and reacting to
- Contamination Control Engineers monitor data and plots on SPC charts
 - Watches trends over time
 - Shares concerns with Process Engineers
 - Shares concerns with Central Contamination Control team

FOD Trending and SPC at ATK-Thiokol

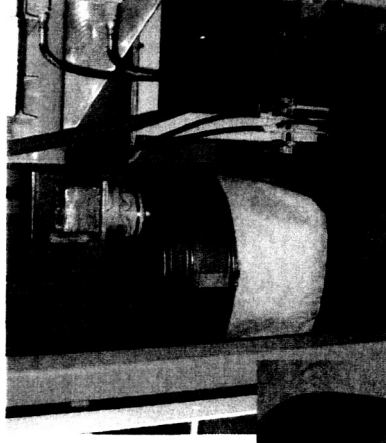
Propellant FOD

- We trend 3 types of FOD in propellant production

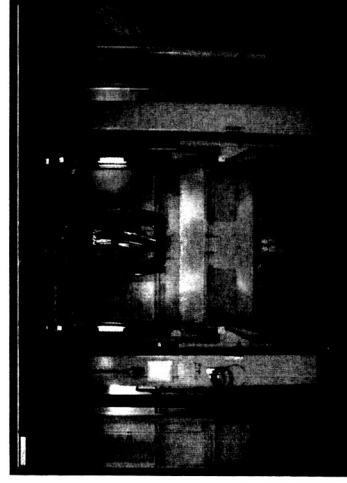
- 1st – FOD in a Motor (detected by x-ray)



- 2nd – FOD in a Propellant Stream (caught on a screen)



- 3rd – FOD in a critical FO zone



FOD Trending and SPC at ATK-Thiokol

Propellant FOD

- Historical data shows that the cleaner we keep our FO zones, the less FOD we have in the propellant stream
- Once FOD is detected in a motor, it's hard or impossible to remove it
- We can do something about FOD in a critical FO zone
- And because we have shown a correlation between FO zone FOD and FOD in propellant, Operations can see the effect of keeping the FO zone clean

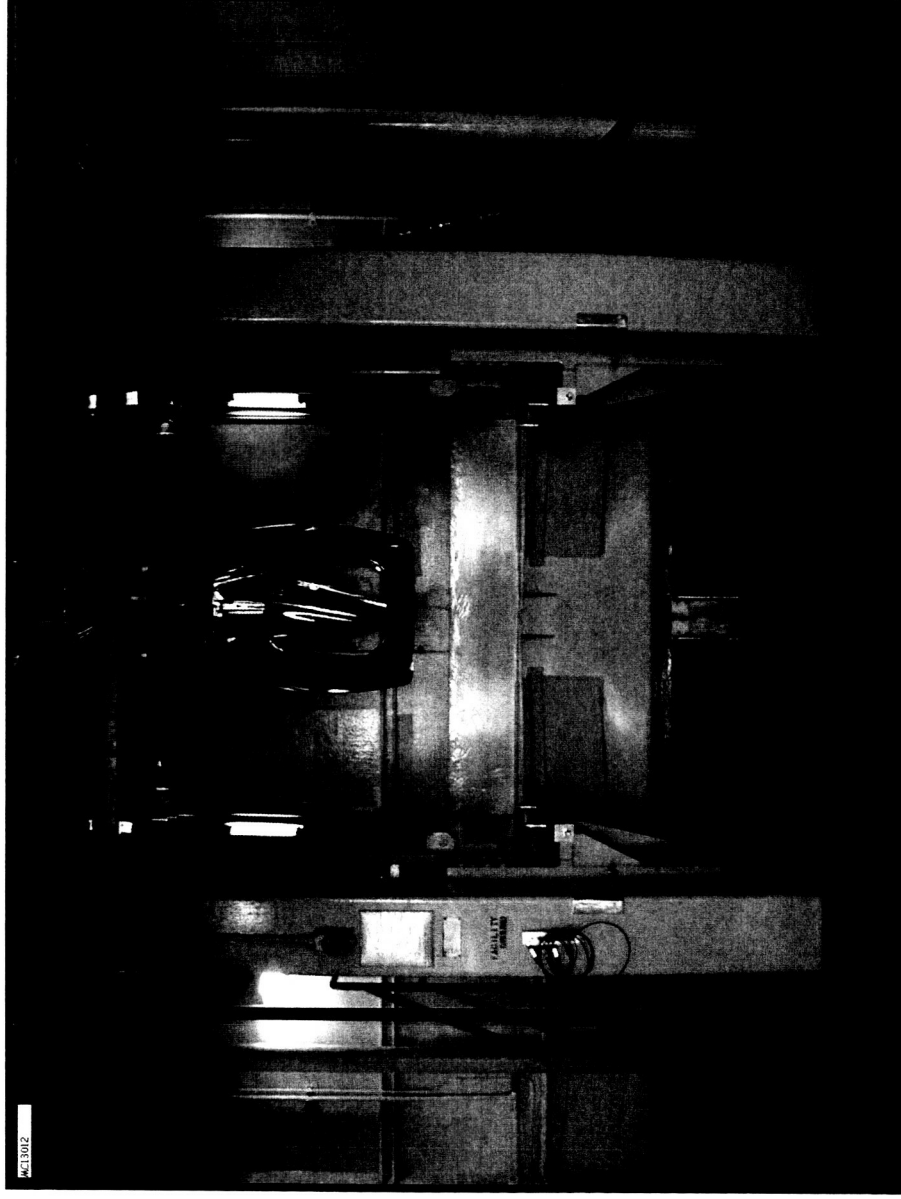


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FOD Trending and SPC at ATK-Thiokol

Propellant FOD

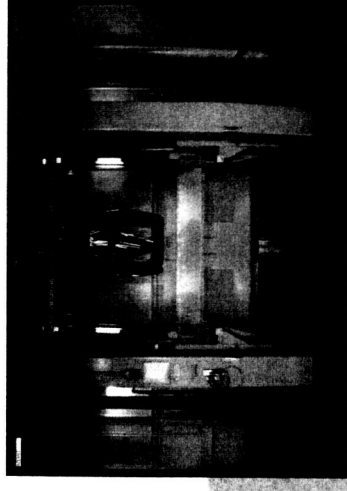
- FO Zone - Definition



FOD Trending and SPC at ATK-Thiokol

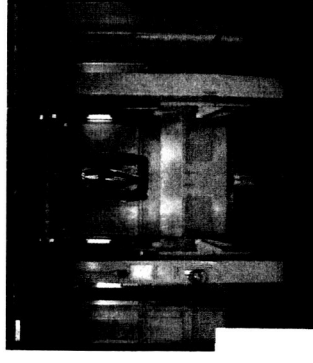
Propellant FOD

- Some worst case scenarios of FO Zone FOD



FOD Trending and SPC at ATK-Thiokol

Propellant FOD



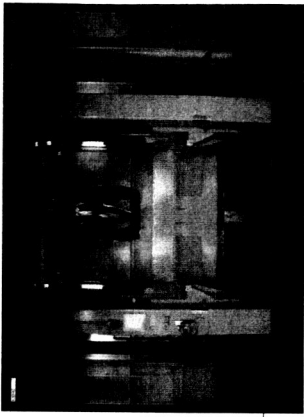
- FO Zone FOD – When to Count
- Lessons Learned: FOD can be looked at by month and by building

M-325 March FOD chart



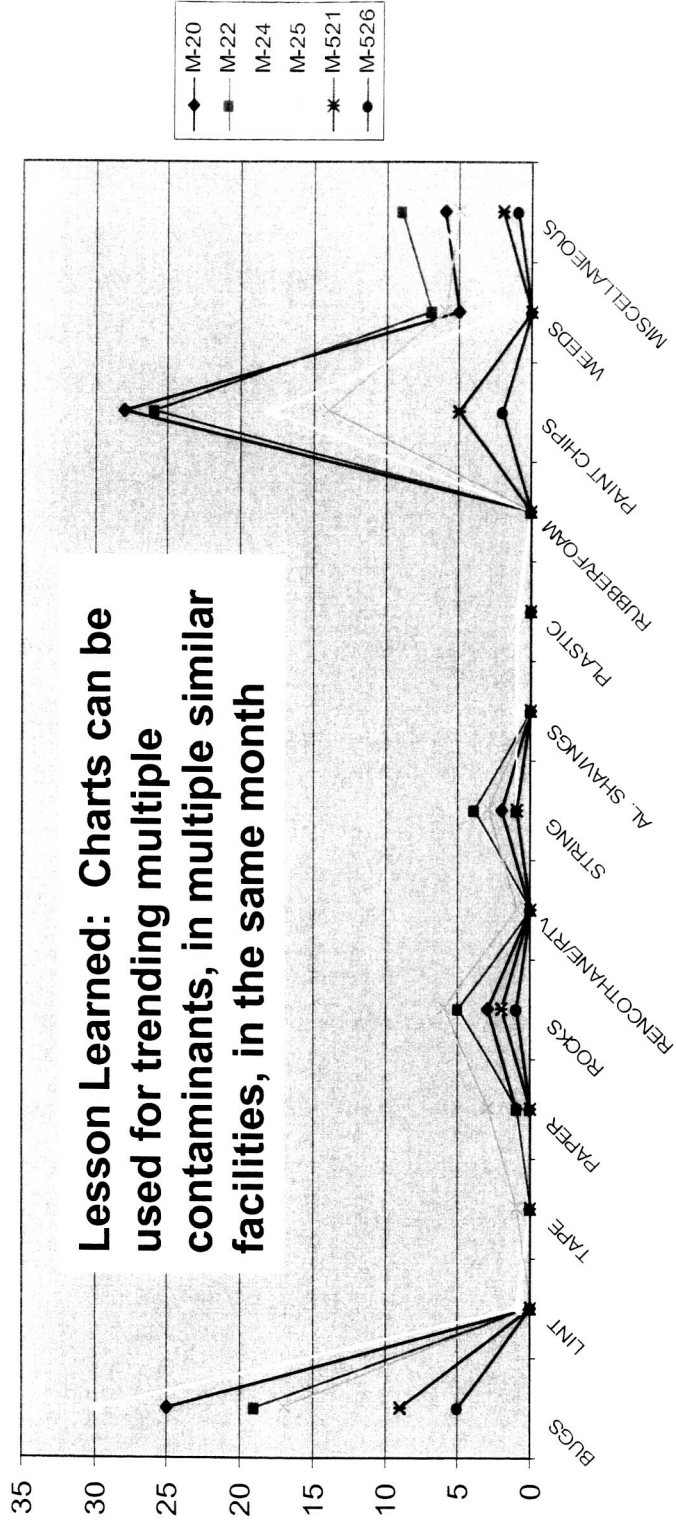
FOD Trending and SPC at ATK-Thiokol

Propellant FOD



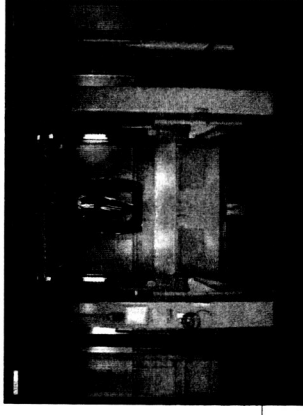
- FOD in Critical FO Zone

MIXING F.O.D CHART (8/28/03 - 9/18/03)



FOD Trending and SPC at ATK-Thiokol

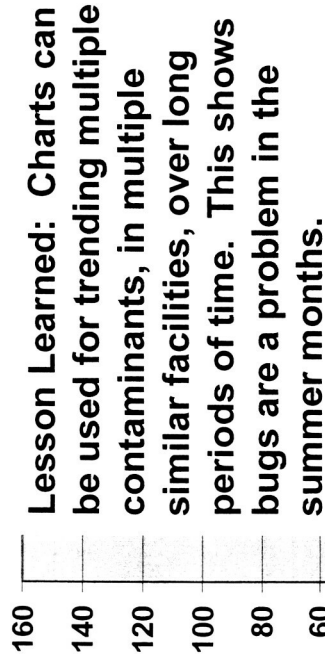
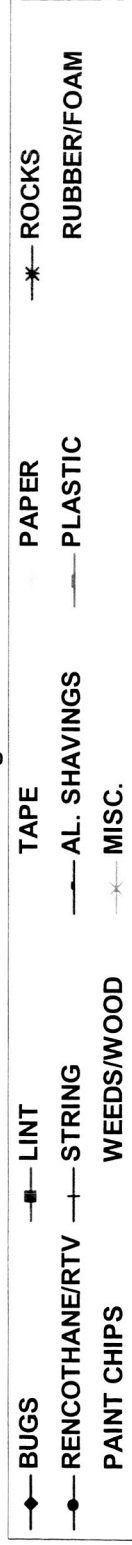
Propellant FOD



- FOD in Critical FO Zone

MIXING AREA FOD SWEEP FINDINGS CY04

11 Buildings



Lesson Learned: Charts can be used for trending multiple contaminants, in multiple similar facilities, over long periods of time. This shows bugs are a problem in the summer months.

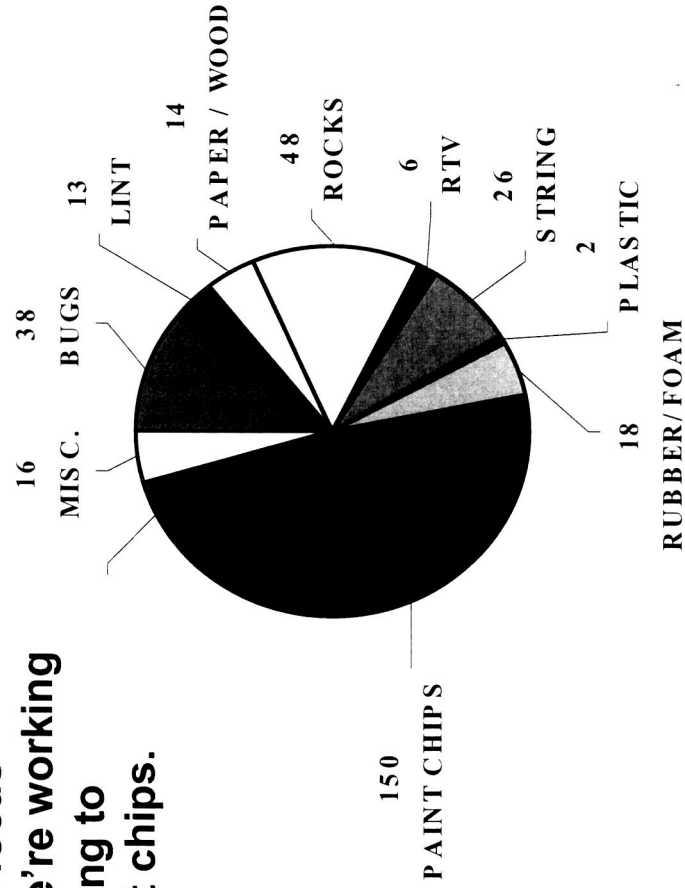
FOD Trending and SPC at ATK-Thiokol

Propellant FOD

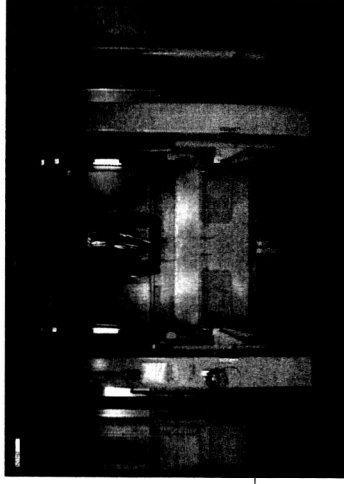
- FOD in Critical FO Zone

Lessons Learned: Pie charts are a good way to show where to focus resources. We're working on a new coating to eliminate paint chips.

M-301 June FOD Findings

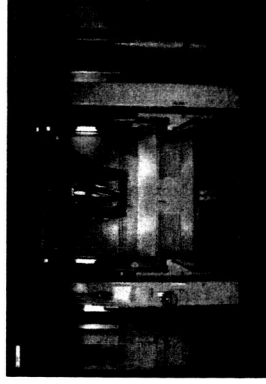


BUGS	38
LINT	13
PAPER / WOOD	14
ROCKS	48
RTV	6
STRING	26
PLASTIC	2
RUBBER/FOAM	18
PAINT CHIPS	150
WEEDS	20
MISC.	16



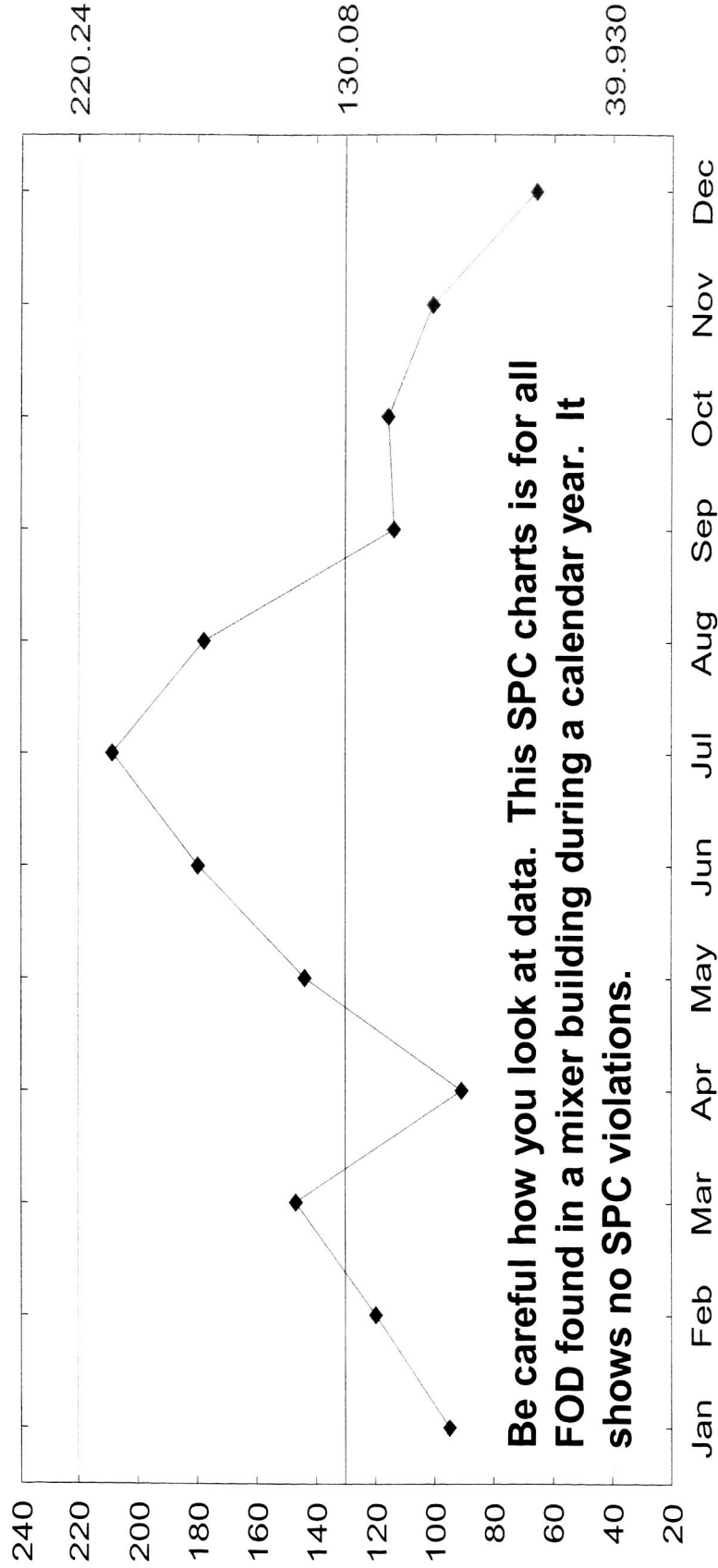
FOD Trending and SPC at ATK-Thiokol

Propellant FOD



- FOD in Critical FO Zone – Yearly Chart

03/02/05
Total Findings

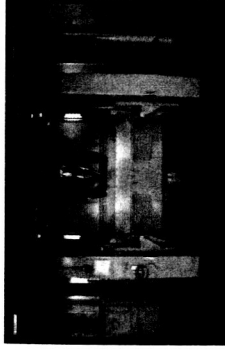




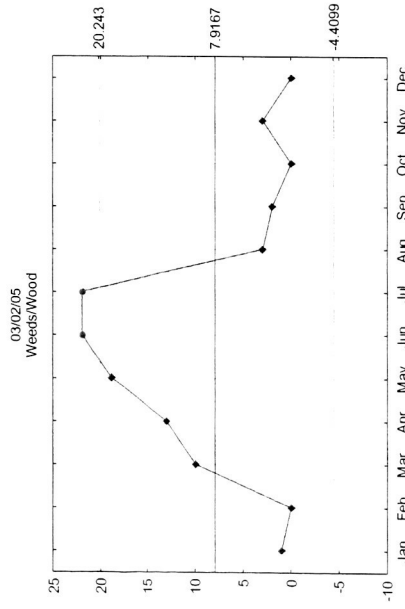
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FOD Trending and SPC at ATK-Thiokol

Propellant FOD

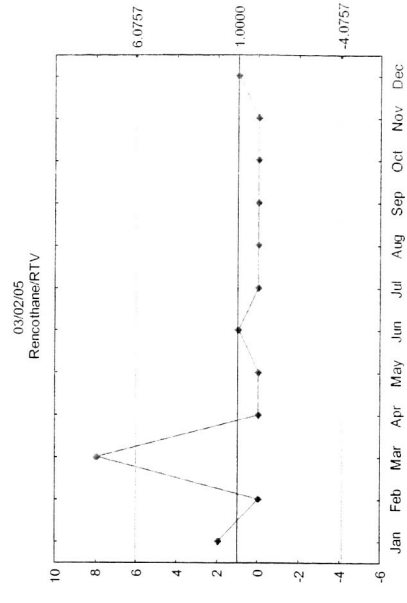
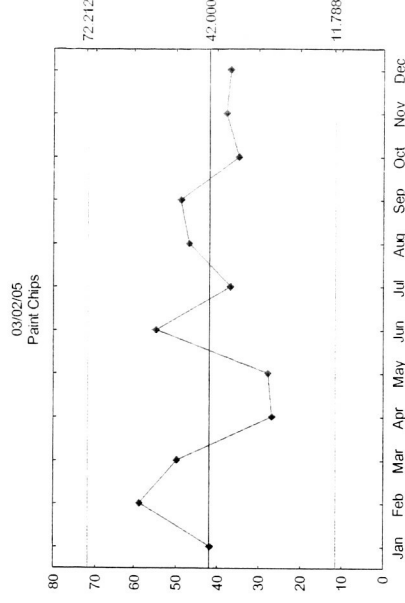
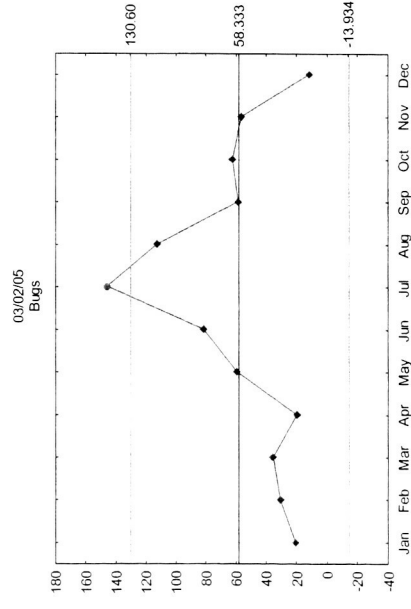


● FOD in Critical FO Zone – Yearly Chart



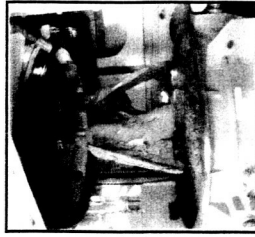
Lessons Learned: If you can live with random variation, SPC charts can be used to statistically look at FOD amounts. It can tell you when something more than random variation has occurred and when to start a special investigation.

If you can tolerate any FOD, tracking with SPC isn't much value.



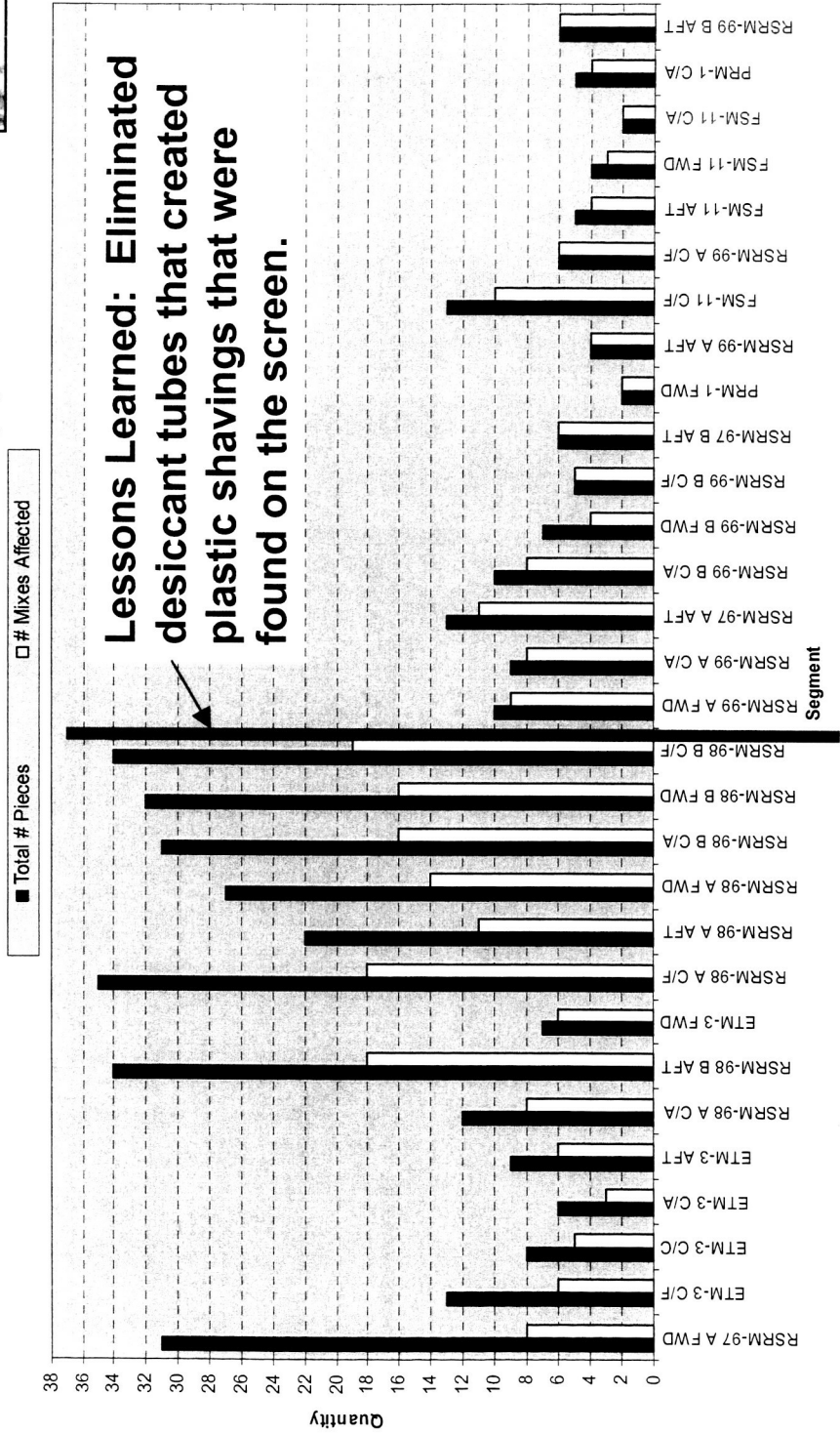
FOD Trending and SPC at ATK-Thiokol

Propellant FOD



- FOD in RSRM Propellant Stream (caught on screen)

11-mesh Mixer Screen Contamination for Last 30 Cast Campaigns



FOD Trending and SPC at ATK-Thiokol

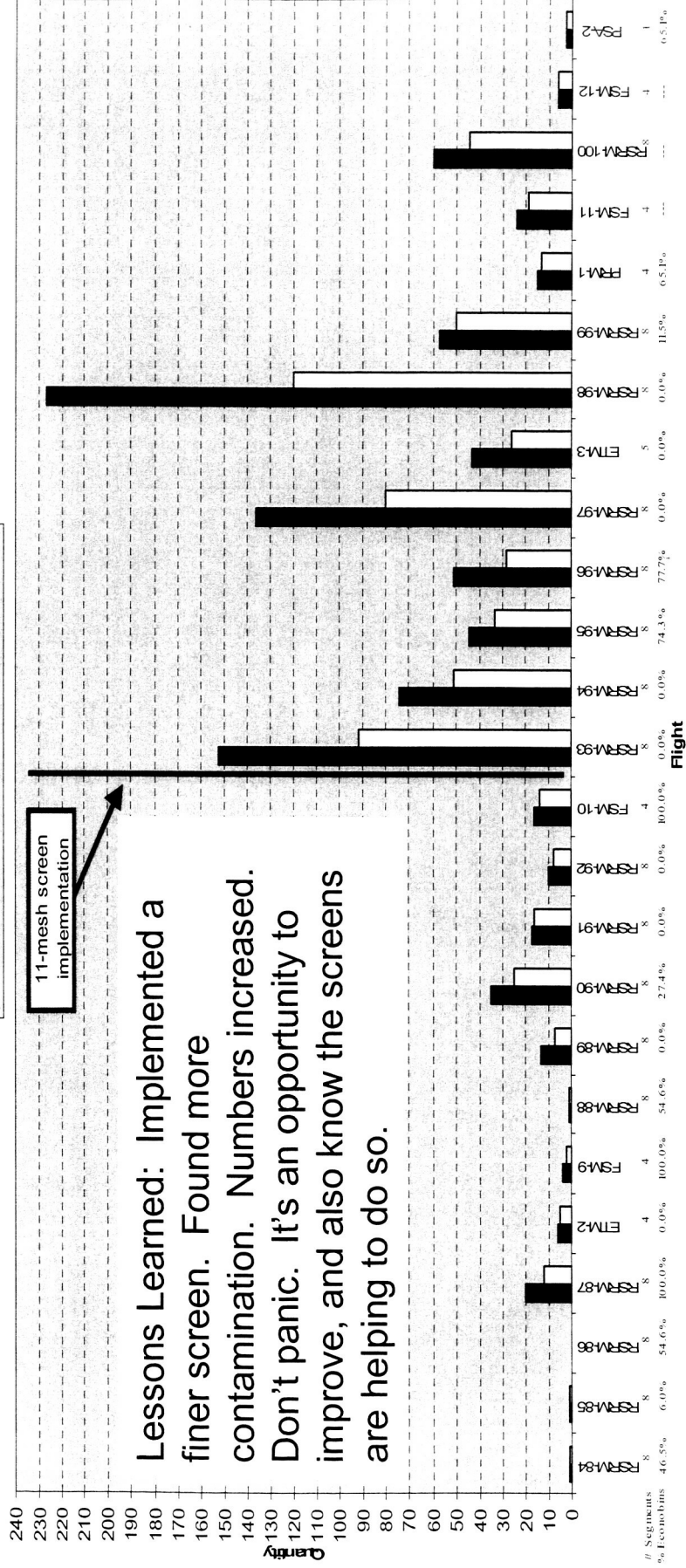
Propellant FOD



- FOD in RSRM Propellant Stream (caught on screen)

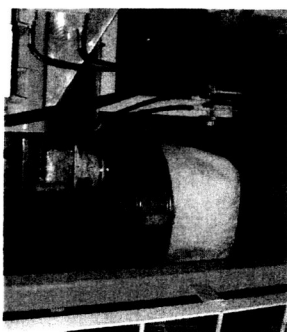
Mixer Screen Contamination per Flight Set

■ Total # Pieces □ # Mixes Affected



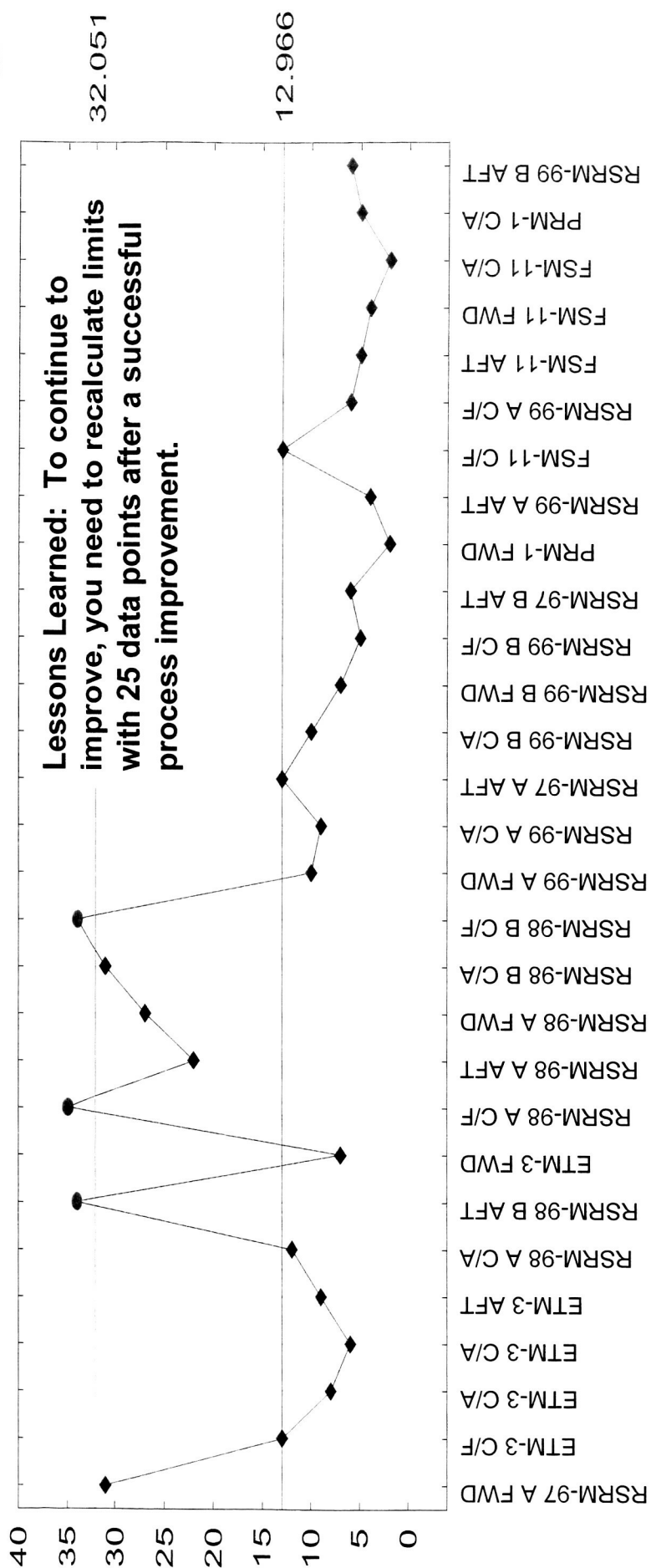
FOD Trending and SPC at ATK-Thiokol

Propellant FOD

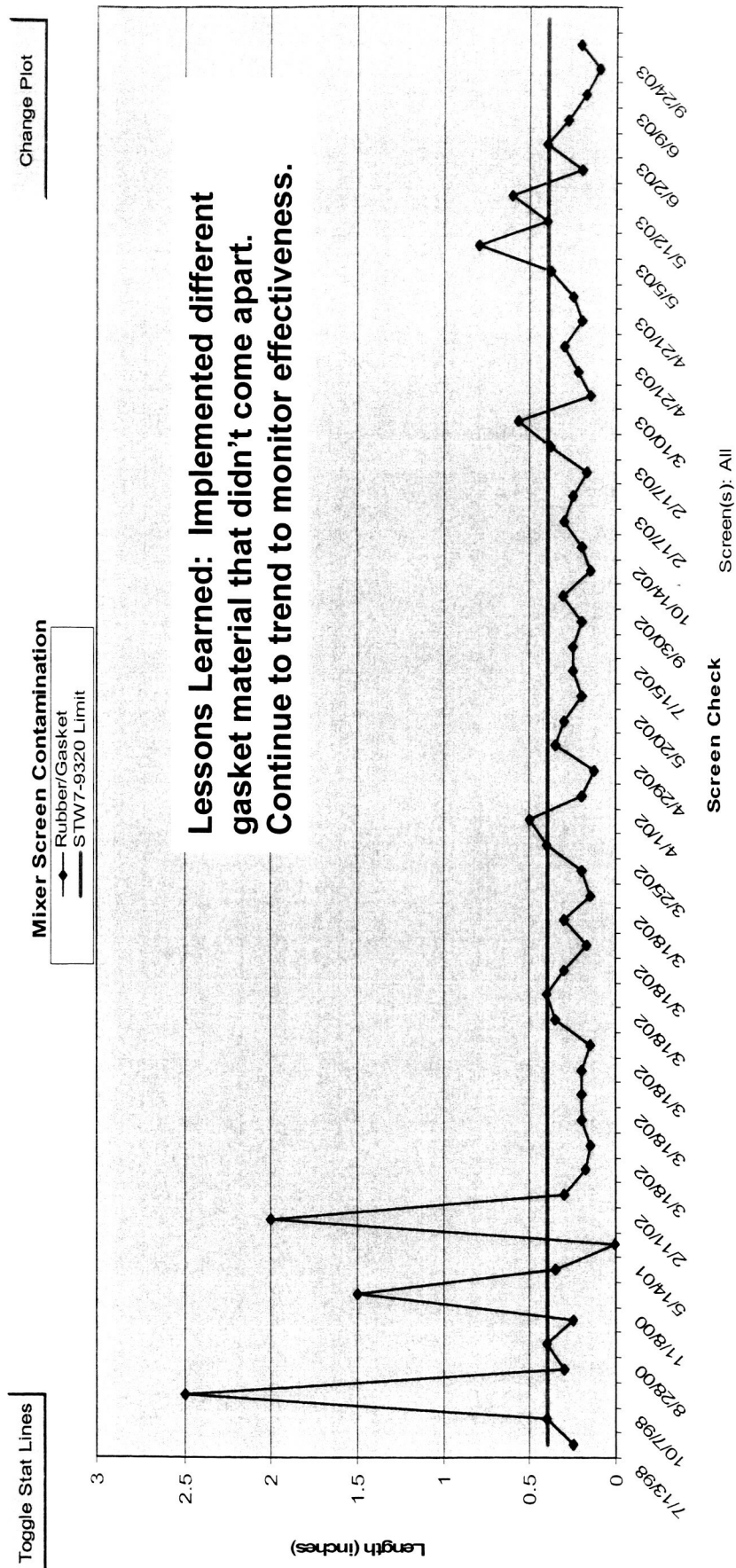
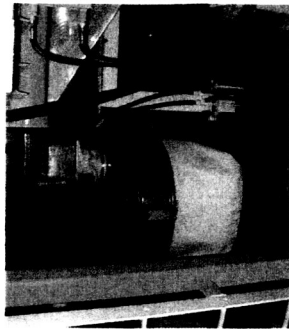


- FOD in RSRM Propellant Stream (caught on screen)

03/03/05 Pieces of FOD

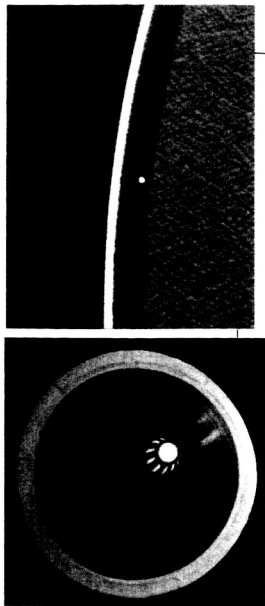


- FOD in Raw Material Screen (caught on screen)



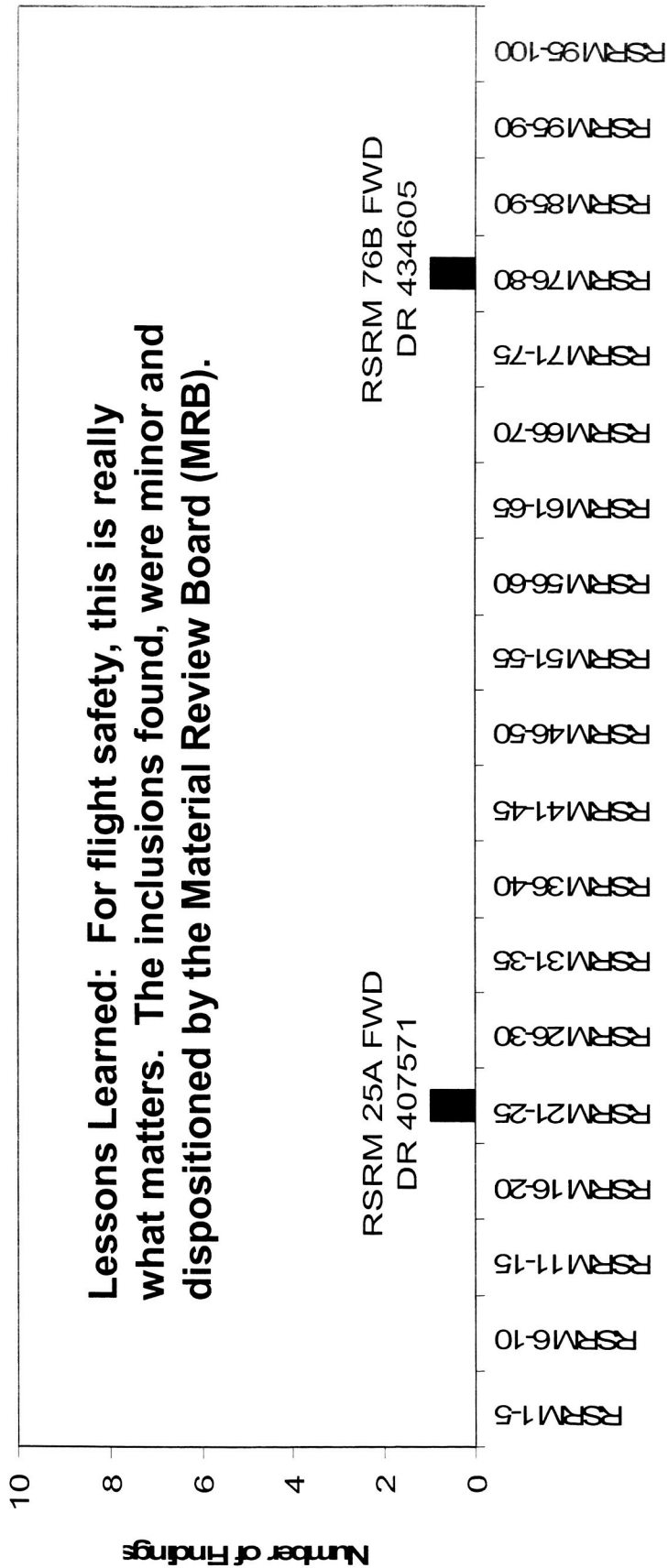
FOD Trending and SPC at ATK-Thiokol

Propellant FOD

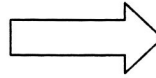


- FOD in Motor

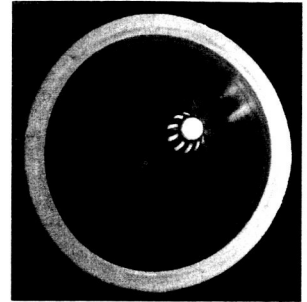
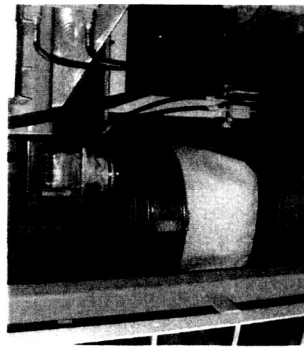
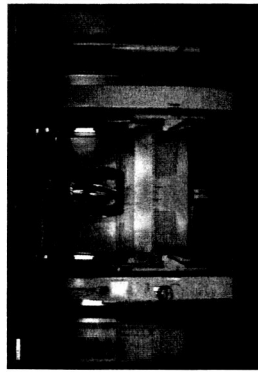
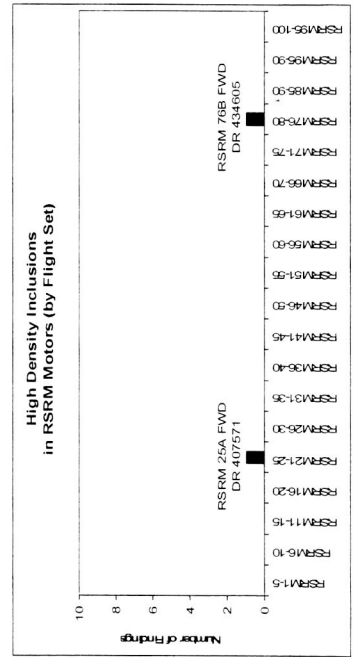
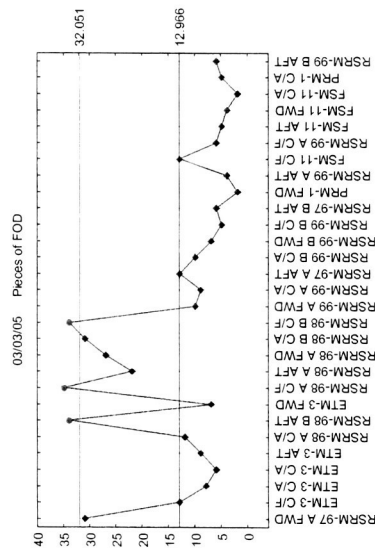
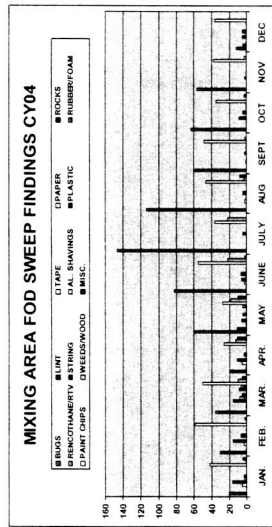
High Density Inclusions
in RSRM Motors (by Flight Set)



A reduction in FOD within a FO zone, leads to



A reduction in FOD in a solid rocket motor, which leads to less risk and happier customers



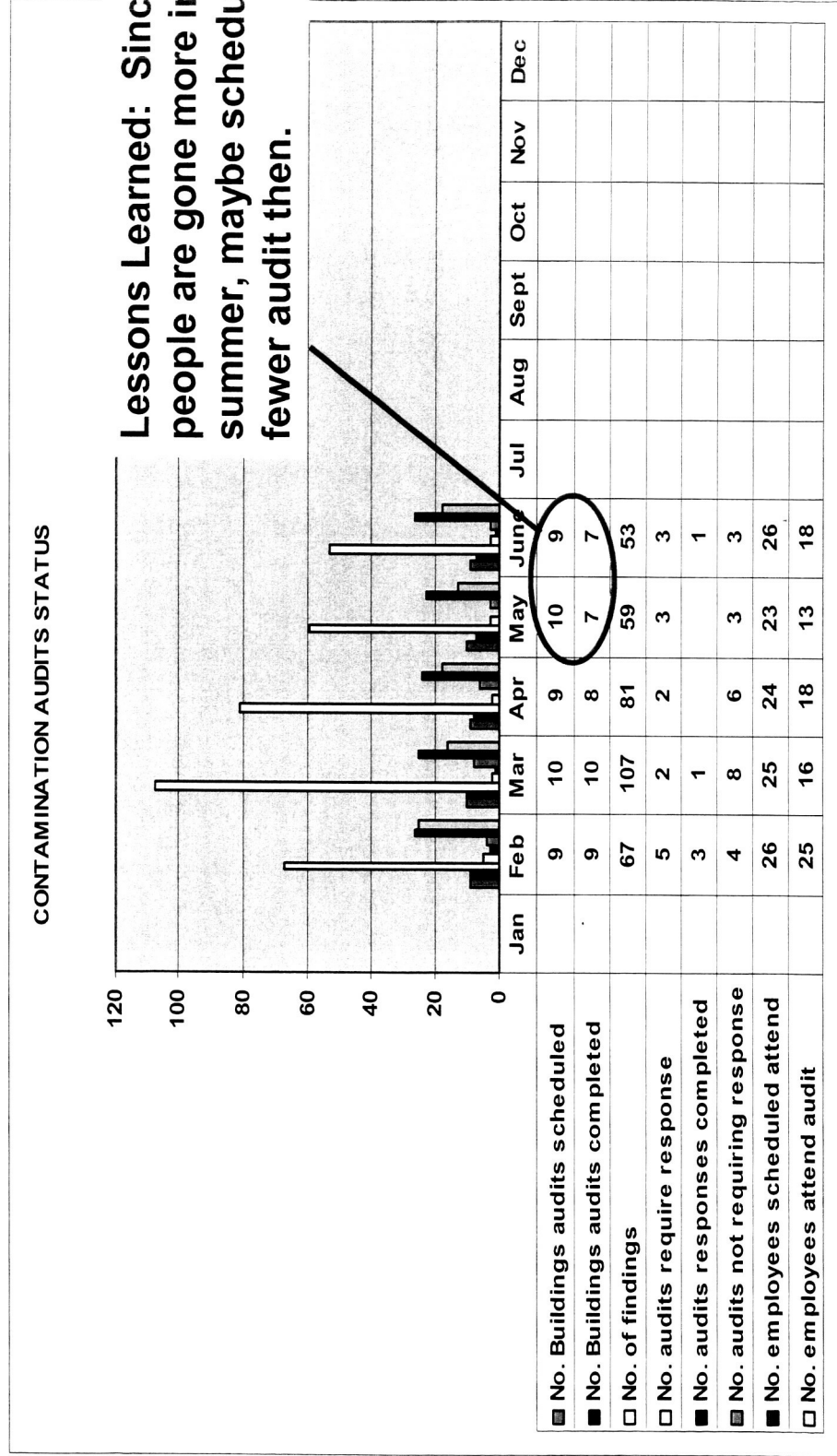


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FOD Trending and SPC at ATK-Thiokol

Propellant FOD

- Contamination Audit - Trending





ATK THIOKOL

FOD Trending and SPC at ATK-Thiokol

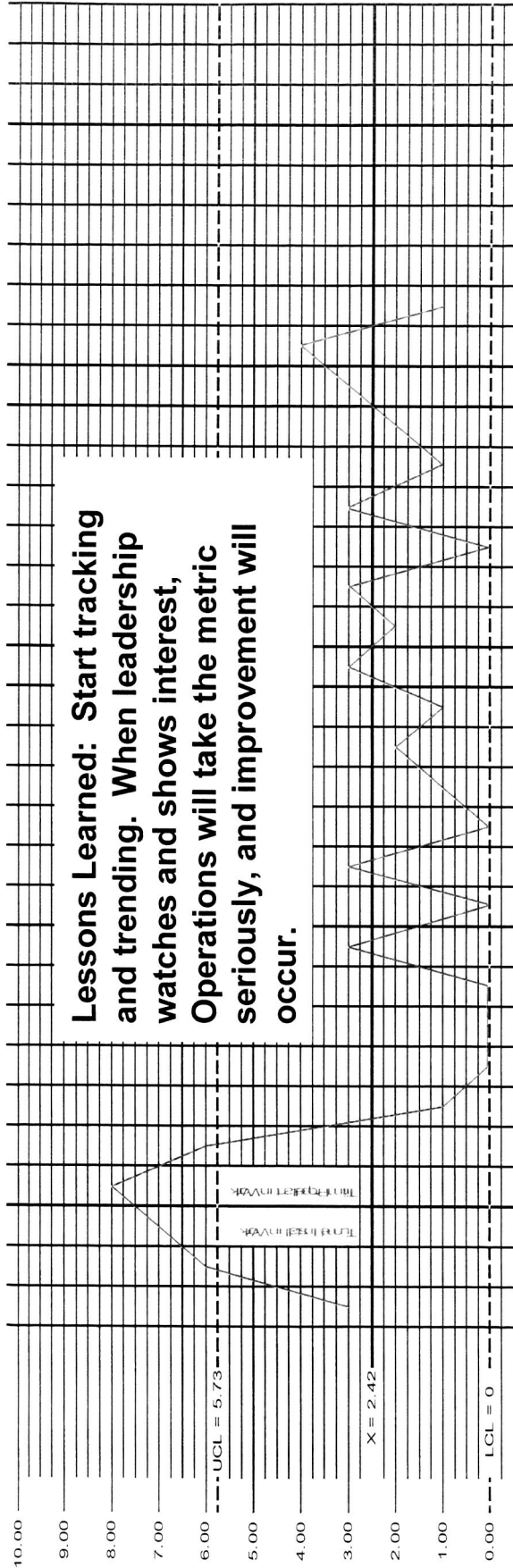
Propellant FOD

- Contamination Audit - Trending

CONTROL CHART - HOUSEKEEPING

AVERAGE CONTAMINATION CONTROL FINDINGS PER AUDIT FOR FINAL ASSEMBLY WORK CENTER

AVERAGES (X BAR CHART) X = 2.420 UCL = 5.73 LCL = 0.00



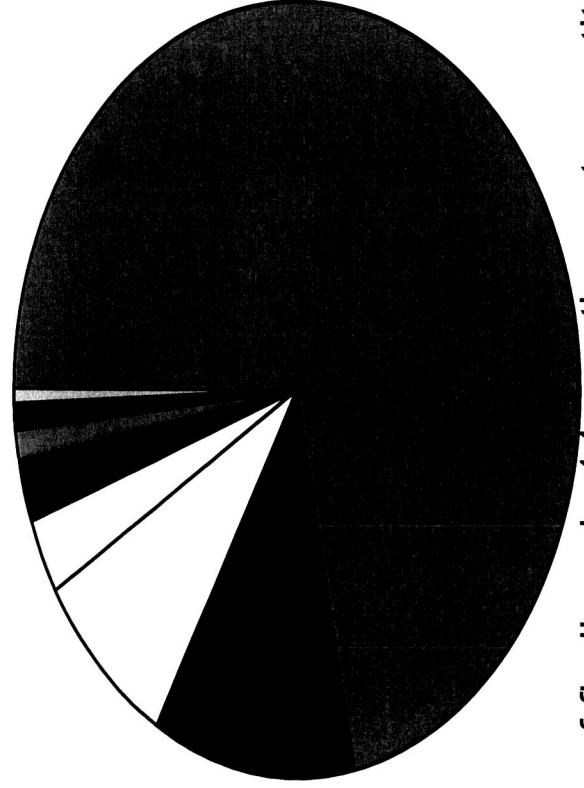
= Required data fields

FOD Trending and SPC at ATK-Thiokol

Propellant FOD

- Where Contamination is Found - Trending

Lessons Learned: Data can be looked at in various ways.
This pie chart looks at FOD in raw materials, as opposed to a process or facility.



Number of findings in 14 months, not quantity



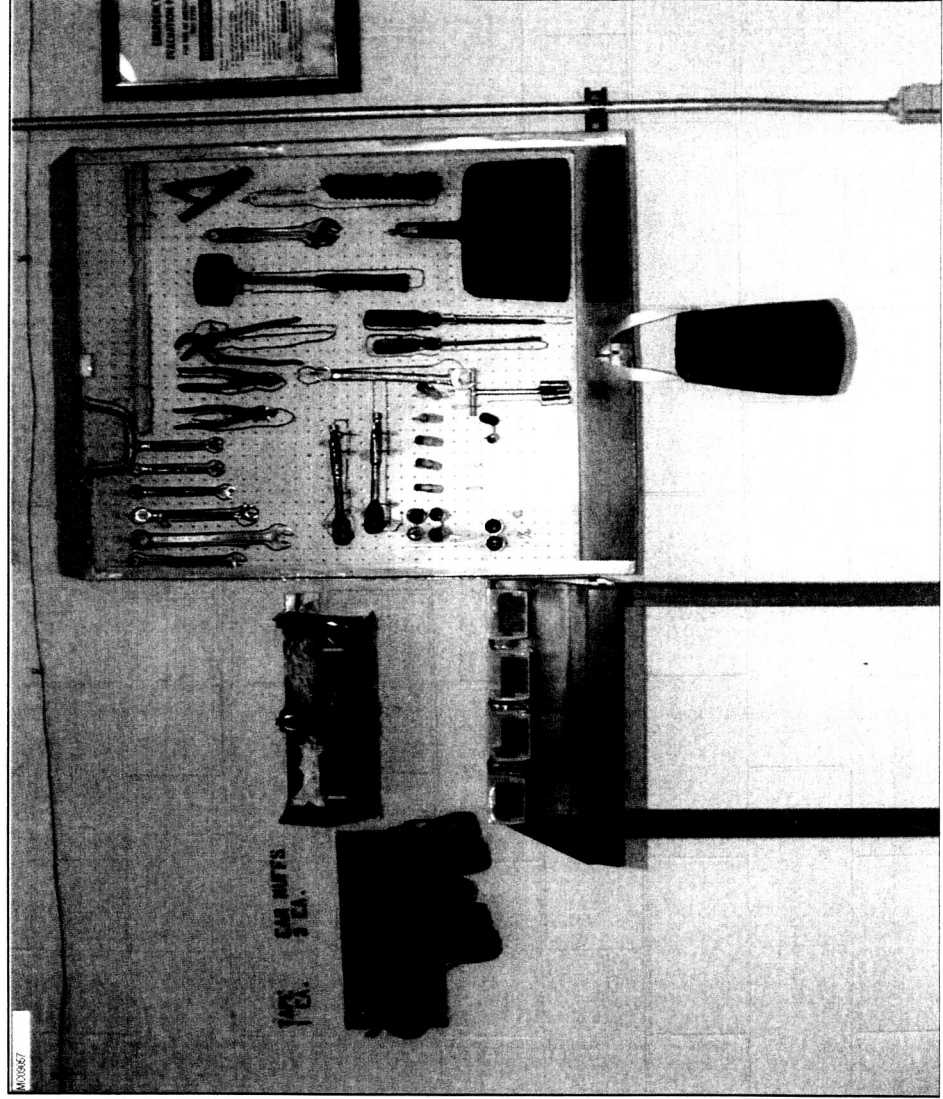
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FOD Trending and SPC at ATK-Thiokol

Propellant FOD

Use Data to Find and Eliminate Source of FOD

Lessons Learned: A clean environment, with tool control, and a FO bag, is a good start.



FOD Trending and SPC at ATK-Thiokol

How We Do SPC

- Management supports SPC/Trending
 - Participate in regular data reviews
 - Funds enhancement projects
- Engineering leads team to determine which parameters to track
 - Keep operators involved. They are experts
- Engineers set-up SPC charts
- Operators collect the data, and plot some of it real-time on SPC charts

FOD Trending and SPC at ATK-Thiokol

How We Do SPC

- Some data is sent to engineering for plotting
- Team analyze data and determine how to react
 - FOD on screens – Determine source
 - Work with raw material vendor
 - Fix sources in-house
 - FOD on FO Zones - Determine top sources
 - Attack and resolve

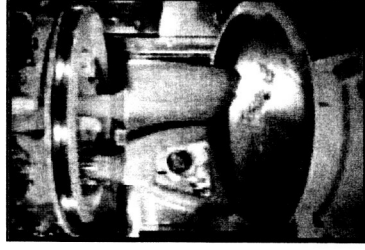
FOD Trending and SPC at ATK-Thiokol

Philosophy

Flight Safety is an issue. So is Industrial Safety.



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Foreign Objects (FO)

- Keep focus on a clean workplace program
- React to industry data
- Find root cause and implement solid corrective actions
- Invest in contamination control (time, management support, \$\$)
- Work with suppliers
- Measure progress
- **Look harder – this is a good thing!**

NOTE: This incident reflects one caused by lightning, where no one was hurt, but with FOD, the potential exists!